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Title of Thesis: Technology Assessment for Designing Communication Requirements of Microgrid

Abstract

The motivation for this research work arose due to lack of availability of standardized communication for operation and control of microgrids. Although many communication technologies and protocols have been proposed for communication in smart grid / microgrid. However, most of these approaches present challenges of feasibility, flexibility and interoperability. Hence the work carried out, in order to write this thesis, intends to abridge the identified gap by designing an IEC 61850 standard based communication for microgrids. The major contributions of this research work are:

IEC 61850 Information Modeling for Electrical Power System Components:

The information modelling is a method of providing standardized syntax, semantics and hierarchical structures to the data that is exchanged among different devices and systems. There were many attempts to develop interoperable information models for different power system components through standards such as the IEC 61499, IEC 60870-6 / TASE.2, IEC 61970 etc. However, all these standards do not address about a unified approach for developing a common information model based on object oriented and interoperability approach. In this regard, TC 57 working group of IEC has published IEC 61850 standard series containing the generic information models in terms of logical nodes and data objects for different components of power system. In this thesis, we tried to develop such holistic information models for different components of microgrids based on IEC 61850 standards. Further, in this work new logical nodes were developed for those components which were not covered by IEC 61850 standards such as controllable loads, Solar Home Systems, smart meters, and DSTATCOM.

IEC 61850 based Energy Management automation in microgrids:

Energy management in microgrids is traditionally achieved through the control capabilities of power electronics converters associated with DERs. Hierarchical controllers such as primary, secondary and tertiary controllers operate in coordination for achieving the energy management function. Hierarchical control relies on communication for coordination between Microgrid Central Controller (MGCC) and the local controller of each DER. The

work carried out under this objective intends to make the above communication standardized and interoperable by implementing it with IEC 61850. This work has also presented IEC 61850 based design and modeling of Intelligent Electronic Devices (IEDs) for different types of DERs, along with the design of structure and size of communication messages required, for energy management in microgrid. Further, in this work the proposed design and modeling is validated by implementing it on a test microgrid system. Dynamic performance of whole communication architecture, for the test microgrid, is evaluated in terms of End-to-End (ETE) delay and throughput for different topological configurations in order to test the design feasibility and also to find the suitable configuration. In order to test the microgrid communication design in real time, a system-in-the-loop (SITL) platform consisting of real IEDs and network simulator is developed in this work. Results from these SITL real time experiments provides useful insights for validating the proposed communication design for microgrids. It can also be used for pre-testing of the microgrid communication before the deployment is planned in the field.

Communication design for charging management of Electric Vehicle (EV) in a microgrid:

In order to harness the bidirectional power transfer capabilities of EVs in microgrids, an effective charging and discharging management scheme based on energy management scheduling of EVs is developed in this thesis. It has been noted that communication between EV and different actors, i.e. grid (Charging Station) and infrastructure (Road Side Unit (RSU)) is vital for effective implementation of EV charging management scheme in microgrids. This communication-based charging station allotment scheme has two modes of communication i.e. EV to Infrastructure (V2I) and EV to charging station (V2G). In this work, to make the V2I communication standardized and interoperable IEC 61850-9-8 information models over IEEE 1609 WAVE services has been proposed. Similarly, for V2G communication IEC 61850-90-8 information models and mappings over ISO/IEC 15118 services has been proposed. Through this proposed harmonized communication, a common standardized and interoperable communication configuration for EV interactions has been developed which enables plug and play operation.

For performance evaluation and analysis of the different communication configurations over different communication technologies for implementing different functions, in terms of ETE delay, throughput, jitter etc., was carried out by running extensive simulations based on Riverbed Modeler network simulator tool.